METHOD AND APPARATUS SUPPORTING A SLIDER HAVING MULTIPLE DEFLECTION RAILS IN A NEGATIVE PRESSURE POCKET FOR A HARD DISK DRIVE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to sliders for hard disk drives, and more particularly to self-loading negative pressure air bearing sliders for use with rotary actuators.

2. Background Information

The read-write head is embedded in a slider. The slider floats on a thin air bearing a very short distance above the rotating disk surface. Typically, the slider has a trailing end in which the read-write head is mounted.

Disk rotation drags air under the slider. The air bearing is generated between the flying slider and the rotating disk. The skin friction on the air bearing surface of the slider creates an aerodynamic lifting force. This causes the slider to lift and fly above the disk surface. Today, most conventional sliders include a sub-ambient pressure region around slider centroid. This sub-ambient pressure zone develops negative pressure that counteracts the aerodynamic lifting force developed along the air bearing surface. These lifting and sub-ambient forces combine to stabilize slider's flying environment.

In the hard disk drive industry, there is a continuous economic incentive for greater bit density on the disk surfaces. This places a strong emphasis on extremely narrow flying gaps between sliders and the rotating disk surfaces over which they fly.

Today, many hard disk drives employ sliders designed to operate at some level of interference between the slider and the contaminating particles found on or near the rotating disk surface.

Because current conventional sliders fly very close to the disk surface, the particle contamination between the slider and the rotating disk surface is a serious problem, affecting the reliability of data access operations.

Because of the small size of these particles, they can easily be taken up into the air flow. They flow along with the main air stream, interacting with the slider and the rotating disk interface. The particles tend to accumulate on the slider surface, often changing the characteristics of the slider to rotating disk surface interface. This tends to destabilize how the slider flies over the rotating disk surface, and may cause abrasion on the disk surface. The abrasion may result from scratches on the disks, embedding some of these particles in the rotating disk surface. Both of these effects can seriously reduce the operational reliability of the hard disk drive.

While it would be best if there were no floating particles inside of the hard disk drive, it is not possible to make an economical, completely clean, hard disk drive. Additionally, normal operation of a hard disk drive may generate new particles.

What is needed is substantial reduction of contamination of the slider-rotating disk surface interface by safely rejecting these floating particles between the flying slider and the rotating disk, especially around the read-write head.

What is needed is a flying head slider experiencing less failure from particle contamination, in particular less abrasive wear and fewer disk surface scratches.

Magnetic spacing modulation refers to modulations in the magnetic field between the read-write head and a track being accessed on the rotating disk surface. These modulations result from collisions of particles with the slider, which causes the flying height to vary. A slider is needed, with less magnetic spacing modulation and improved stability in its flying over the rotating disk surface.

BRIEF SUMMARY OF THE INVENTION

The invention includes an air bearing surface for a slider. The air bearing surface contains at least two deflection rails between a leading air bearing surface and a central island containing the read-write head. A gap separates the left and right deflection rails.

During the slider's normal operation, incoming particles may collide with at least one of the deflection rails and deflect away from the central island and the read-write head. These deflection rails substantially reduce particle contamination problems at the interface of the slider with the rotating disk surface. This interface directly affects the reliability of the read-write head in accessing tracks on the rotating disk surface.

The gap supports means for diminishing additional negative pressure in the negative air pressure pocket. The gap may minimize the accumulation of debris behind the rejection rails.

The invention includes the head gimbal assemblies including these sliders, the actuator arms coupled to the head gimbal assemblies, the actuator assemblies including at least one of the actuator arms, and the hard disk drives including the actuator assemblies. The invention also includes methods making the sliders, the actuator arms, the actuator assemblies, and the hard disk drives. The invention includes the products of these manufacturing methods.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and features of the present invention, which are believed to be novel, are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages, may best be understood by reference to the following description, taken in connection with the accompanying drawings, in which:

Figure 1A is a perspective view of the conventional slider supporting a negative pressure air bearing when flying above a rotating disk surface;

Figure 1B is a side view of a conventional slider flying over rotating disk;

Figure 2A is a perspective view of one embodiment of a slider air bearing surface containing a left deflection rail in front of a right deflection rail in the negative pressure pocket;

Figure 2B shows a bottom view of the slider air bearing surface of Figure 2A;

Figures 3A and 3B show bottom views of an embodiment of a slider air bearing surface containing a right deflection rail in front of a left deflection rail in the negative pressure pocket;

Figures 4A and 4B show bottom views of another embodiment of a slider air bearing surface utilizing a curved left deflection rail in front of a bent right deflection rail in the negative pressure pocket;

Figure 5 shows a bottom view of another embodiment of a slider air bearing surface utilizing a central deflection rail, a left deflection rail and a right deflection rail in the negative pressure pocket;

Figure 6A shows a refinement of Figure 5, further including a second left deflection rail and a second right deflection rail;

Figures 6B to 6C shows refinements of Figures 2A and 2B, further including a second left deflection rail and a second right deflection rail;

Figures 6D shows a refinement of Figures 2A and 2B, further including a second left deflection rail;

Figures 7A and 7B shows details of the operation of the slider air bearing surface of Figure 5;

Figure 7C shows a head gimbal assembly including a slider presenting the air bearing surface of Figures 2A to 7B;

Figure 8 shows an a hard disk drive 110 with the actuator assembly included in a voice coil motor assembly, containing actuator arms, positioning at least one head gimbal assembly;

Figure 9A shows a head disk drive including the voice coil motor assembly mounted through the actuator pivot to the disk base plate, coupling through the head gimbal assembly over a rotating disk surface;

Figure 9B shows a detail of Figure 9A, where the actuator arm, coupling through the head gimbal assembly to position the slider to access a track on the rotating disk surface; and

Figure 10 shows a simplified, exploded view of the primary components of the hard disk drive using the voice coil motor assemblies of Figures G9 and 9A.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description is provided to enable any person skilled in the art to make and use the invention and sets forth the best modes presently contemplated by the inventors for carrying out the invention. Various modifications, however, will remain readily apparent to those skilled in the art, since the generic principles of the present invention have been defined herein.

Table One of named elements, reference numbers and Figures.

Named element	Reference	Figures
Leading edge step	2	1A to 7A
Leading air bearing surface	4	1A to 5
Left leading air bearing arm	4A	1A, 2A to 5
Right leading air bearing arm	4B	1A, 2A to 5
Negative pressure pocket	6	1A to 7B
Left island ledge	8	1A to 5, 7A, 7B
Left island	10	1A to 5, 7A, 7B
Read-write head	12	1A to 5, 7A to 7C, 9B
Central island	14	1A to 5, 7A, 7B
Central island ledge	16	1A to 5, 7A, 7B
Right island	18	1A to 5, 7A, 7B
Right island ledge	20	1A to 5, 7A, 7B
Leading face of slider	22	1A, 2A
Principle axis	24	1A, 2A, 3A, 4A, 5, 9B
Leading edge	26	1A to 5, 7A, 7B
Trailing edge	28	1A to 5, 7A, 7B
Air flow	30	1A to 2A

Table One of named elements, reference numbers and Figures.

Named element	Reference	Figures
Left deflection rail	50	2A to 7B
Left deflection front face	50A	2A to 5, 7B
Left deflection back face	50B	2A, 3A, 4A, 5
Left deflection rail length	52	3A
Left deflection rail height	54	2A
Left deflection rail angle	56	2A, 3A, 4A, 5
Left deflection rail width	58	2A, 3A, 4A
Central deflection rail	60	5, 6A, 7A, 7B
Central deflection rail right front face	60A	5, 7A, 7B
Central deflection rail left front face	60B	5, 7A, 7B
Central deflection rail back face	60C	5
Central deflection rail right angle	66A	5
Central deflection rail left angle	66B	5
Right deflection rail	70	2A to 7B
Right deflection front face	70A	2A to 3B, 5, 7B
Right deflection front face left part	70A1	4A, 4B
Right deflection front face right part	70A2	4A, 4B
Right deflection back face	70B	2A, 3A 4A, 5
Right deflection back face left part	70B1	4A, 4B
Right deflection back face right part	70B2	4A, 4B
Right deflection rail length	72	3A
Right deflection rail height	74	2A
Right deflection rail angle	76	2A, 3A, 4A, 5
Right deflection rail width	78	2A, 3A, 4A, 5

Table One of named elements, reference numbers and Figures.

Named element	Reference	Figures
Air current into gap G1 between rails	82A	2B, 3B, 4B
Air current through gap G1 between rails	82A1	2B, 3B, 4B
Air current into rail and left rail gap G2	88A2	7A
Air current into from rail and left rail gap G3	88B2	7A
Left air current through rail gap G1	88C	7A
Right air current through rail gap G1	88D	7A
Left deflection rail incoming particle	90A	2B, 3B, 4B, 7B
Left deflection rail deflected particle	90B	2B, 3B, 4B, 7B
Right deflection rail incoming particle	92A	2B, 3B, 4B, 7B
Right deflection rail deflected particle	92B	2B, 3B, 4B, 7B
Left side incoming particle	94A	7B
Left side deflected particle	94B	7B
Right side incoming particle	96A	7B
Right side deflected particle	96B	7B
Air bearing surface of slider	100	1A to 5, 7C
Slider	102	1A, 2A, 7C, 9B

Table One of named elements, reference numbers and Figures.

Named element	Reference	Figures
Micro-actuator	104	7C, 9B
Flexure	106	7C
Hard disk drive	110	8 to 10
Disk base plate	112	9A to 10
Voice coil	114	8 to 9B
Actuator pivot	116	8 to 9B
Voice coil motor assembly	118	8, 9A, 10
Yolk top plate	120	8, 9A
Yolk bottom plate	122	8
Load beam	130	7C
Actuator arm	150	8 to 9B
…	152, 154, 156	8
Actuator assembly	158	8, 9B
Head gimbal assembly	160	7C to 9B
…	162, 164, 166	8
Axis of disk rotation	168	8 to 9B
Spindle motor	170	10
Disk spacer	172	10
Disk Clamp	174	10
Spindle motor hub	178	10
Disk, First	180	1B, 8, 9A to 10
Disk, Second	182	10
Printed circuit board	184	10
Main flex circuit	186	9A
Flex circuit	188	8, 9A

Table One of named elements, reference numbers and Figures.

Named element	Reference	Figures
Track	190	9B
Inside Diameter	192	9B
Outside Diameter	194	9B
Preamplifier	198	8
Flex connector	200	8
Disk top plate	210	10
Second left deflection rail	250	6A to 6D
Second right deflection rail	270	6A to 6D
Finished depth of slider 102	D0	1A, 2A
Depth of island ledge 20	D1	1A, 2A
Depth of leading air bearing surface 4	D2	1A, 2A
Distance between air bearing surface 100 and the rotating disk 180 surface	D3	1B
First Gap from left deflection to right deflection rail	G1	2A, 3A, 4A, 5 to 6D
Second Gap from right deflection rail to central rail	G2	5, 6A
Third Gap from left deflection rail to central rail	G3	5, 6A
Fourth Gap between second left deflection rail 250 and left deflection rail 50	G4	6A to 6D
Fifth Gap between second right deflection rail 270 and right deflection rail 70	G5	6A to 6C

Figure 1A is a perspective view of the conventional slider supporting a negative pressure air bearing when flying above a rotating disk surface. Figure 1B is a side view of the conventional slider 102 flying over a rotating disk 180.

In Figures 1A and 1B, slider 102 possesses a negative pressure air bearing formed by the air bearing surface 100 interacting with the rotating disk 180. The force causing the slider to fly is due to the rotation of the disk 180 surface below the slider 102. The disk rotation creates a wind providing a lifting force between a leading air bearing surface 4 and a trailing air bearing surface 28. The trailing air bearing surface is part of a central island 14, which includes a read-write head 12. The overall configuration generates a downside force at negative pressure pocket 6. Interaction between the lifting and downside forces reduces the flying height sensitivity with respect to disk velocity as well as increases air bearing stiffness. The leading edge flying height being higher than the trailing edge flying height provides a pitch angle which stabilizes slider flying. However, this pitch angle allows incoming particles to easily pass the leading edge 4, to be squeezed and embedded in the disk surface, or damage the read-write head 12, while passing the trailing edge 14.

The air flow driven by disk rotation under a slider air bearing surface as in Figures 1A and 1B. The air flow is squeezed at leading edge step 4. The slider lifting force is generated from air passing the leading air bearing surface, which includes 4, 4A, and 4B. The squeezed air is rapidly expanded and retarded at negative pressure pocket 6, generating a sub-ambient pressure at the pocket 6, which pulls down the slider. As air passes the trailing edge, it is squeezed between trailing air bearing surface 10, 14, and 22. This generates a positive push-up force acting upon the slider 102.

As in Figure 1B, the air flow in the negative pressure pocket 6 includes an upside expansion with drastically retarded flow speed. During this air expansion in the zone 6, many incoming particles tend to float in the air flow, creating a debris accumulation zone 40. Additionally, particles which are lifted into the air flow, may actually concentrate near the principal axis 24, and stand a high chance of colliding with the central island 14, possibly even colliding with the read write head 12. Particle collisions with the read-write head 12 may damage its reliability. In the following discussion, because of laminar flow characteristics, air streamlines

between the invention's slider air bearing surface 100 and the rotating disk 180 may be mostly parallel.

Figure 2A is a perspective view of one embodiment of a slider air bearing surface 100 utilizing a left deflection rail 50 and a right deflection rail 70 in the negative pressure pocket 6. Figure 2B shows a bottom view of the slider air bearing surface 100 of Figure 2A. The left deflection rail 50 is in front of the right deflection rail 70. As used herein, a first rail is in front of a second rail whenever some part of the first rail is closer to the leading edge 26 than any part of the second rail.

Figures 3A and 3B show bottom views of another embodiment of the slider air bearing surface 100 utilizing a right deflection rail 70 in front of a left deflection rail 50 in the negative pressure pocket 6.

Figures 4A and 4B show bottom views of another embodiment of a slider air bearing surface 100 utilizing a left deflection rail 50 in front of a right deflection rail 70 in the negative pressure pocket 6. The left deflection rail 50 curves. The right deflection rail 70 is bent.

Figure 5 shows a bottom view of another embodiment of a slider air bearing surface 100 utilizing a central deflection rail 60, a left deflection rail 50 and a right deflection rail 70 in the negative pressure pocket 6. Figures 7A and 7B show details of the operation of the slider air bearing surface 100 of Figure 5. The left deflection rail 50 is essentially as close to the leading air surface 4 as the right deflection rail 70.

The central deflection rail 60 is in front of the left deflection rail 50 and the right deflection rail 70. It may be preferred that the left deflection rail 50 and the right deflection rail 70 mirror each other about the principal axis 24.

In Figures 2A, 2B, 3A, 3B, 4A, 4B, 5, 7A, and 7B, the left deflection rail 50 includes a left deflection front face 50A and a left deflection back face 50B. The left deflection rail width 58 is essentially the distance between these two faces 50A and 50B. The left deflection rail 50 has a length 52, arranged at an angle 56 with respect to the principle axis.

In Figures 2A, 2B, 3A, 3B, 5, 7A, and 7B, the right deflection rail 70 includes a right deflection front face 70A and a right deflection back face 70B. The right deflection rail width 78

is essentially the distance between these two faces 70A and 70B. The right deflection rail 70 had a length 72, arranged at an angle 76 with respect to the principle axis.

In Figures 2A, 2B, 3A, and 4A, the right deflection rail 70 extends on both the left and right side of the principal axis 24. The left deflection rail 50 extends on both the left and right side of the principal axis 24.

In Figure 5, the left deflection rail 50 extends only on the left side of the principal axis 24. The right deflection rail 70 extends only on the right side of the principal axis 24. The left deflection rail 50 extends only on the left side of the principal axis 24.

In Figures 2A, 2B, 3A, 3B, 4A and 4B, the left deflection rail 50 and right deflection rail 70 collectively form a deflection barrier. In Figures 5, 7A, and 7B, the left deflection rail 50, the central deflection rail 60, and the right deflection rail 70 collectively form the deflection barrier. It may be preferred that the deflection barrier extends as far to the left of the principal axis as it extends to the right.

Figure 2B shows the operation of the air bearing surface 100 of Figure 2A.

Figure 3B shows the operation of the air bearing surface 100 of Figure 3A.

Figure 4B shows the operation of the air bearing surface 100 of Figure 4A.

Figures 7A and 7B show the operation of the air bearing surface 100 of Figure 5.

In Figures 2B, 3B, 4B, and 7B, an incoming particle 90A may hit the left deflection rail 50, deflecting in a path 90B away from the central island, which includes 14 and 16. An incoming particle 92A may also hit the right deflection rail 70, deflecting in a path 92B away from the central island 14 and 16.

In Figure 7B, an incoming particle 94A may hit the central deflection rail left front face 60B, deflecting in a path 94B away from the central island, which may include 14 and/or 16. An incoming particle 96A may hit the central deflection rail right front face 60A, deflecting in a path 96B away from the central island.

The central island carries the read-write head 12. As shown in Figure 1B, the central island is the region of the air bearing surface 100 which has the narrowest distance from the rotating disk surface, which is labeled D3. If a particle passes near enough to the read-write head 12 while it is accessing a track 190 on the rotating disk 180 surface, as in Figure 9B, one or more

access errors may occur. A particle colliding with one of the deflection rails 50 and 70 tends to be deflected away from the read-write head 12, which tends to increase the overall reliability of the data access operations of the hard disk drive 110.

The invention uses a first gap separating the left deflection rail 50 from the right deflection rail 70 as shown in Figures 2A to 7B. The first gap is labeled G1in Figures 2A, 3A, 4A, and 5 to 6D.

In Figures 2B, 3B, and 4B, the arrow 82A represents the air current going into the first gap G1 between the deflection rails 50 and 70. In these Figures, the arrow 82A1 represents the air current going through the gap G1, which tends to minimize the accumulation of debris behind the deflection rails 50 and 70.

In Figure 7A, there are two additional gaps in front of the first gap G1 between the deflection rails 50 and 70. The arrow 88A2 represents the current of air entering the gap G2, labeled in Figure 5, between the central deflection rail 60 and the left deflection rail 50. This air current predominantly feeds the air current 88C going through the first gap G1. The arrow 88B2 represents the current of air entering the gap G3, labeled in Figure 5, between the central deflection rail 60 and the right deflection rail 70. This air current predominantly feeds the air current 88D going through the deflection rail gap G1. The air currents 88C and 88D tend to minimize negative pressure and the accumulation of debris behind the deflection rails 50 and 70. These gaps and air currents also tend to minimize the accumulation of debris behind the central deflection rail 60.

The invention provides a means for removing debris behind the leading air bearing surface, which includes 4, 4A and 4B. This may occur as a consequence of the interaction of the negative pressure pocket 6 with the deflection rails 50 and 70 in Figures 2B, 3B, and 4B. In Figure 7A, the consequences may include the interaction of the negative pressure pocket 6 with the central deflection rail 60, the left deflection rail 50, and the right deflection rail 70. These interactions with the leading air bearing surface 4 may further include interactions with the left leading air bearing arm 4A and with the right leading air bearing arm 4B.

Figure 2A shows the height 54 of the left deflection rail 50 and the height 74 of the right deflection rail 70. The depth of the leading air bearing surface 4 is shown as D2. The discussion

of these heights may apply to each embodiment of the invention. The height 64 of the central deflection rail 60 is shown in Figure 7A. Typically, height of the islands 10, 14, and 18 is essentially equal to as the depth D2 of the leading air bearing surface 4. The height of the ledges 8, 16 and 20 are essentially equal to, D2 minus D1.

The left deflection rail height 54 and the right deflection rail height 74 both support avoiding contact with the rotating disk 180 surface. These deflection rail heights also avoid contact with the disk 180 surface when the disk drive 110 parks the actuator assembly 158. Parking the actuator assembly 158 entails either placing the head gimbal assemblies 160 to 166 near the outside diameter 194, or placing the head gimbal assemblies 160 to 166 near the inside diameter 192. Hard disk drives 110 parking the head gimbal assemblies 160 to 166 near the inside diameter 192 will be referred to herein as Crash Start/Stop (CSS) hard disk drives. This term and the invention applies to hard disk drives 110 which include at least one head gimbal assembly 160. The central deflection rail 60 as shown in Figures 5 to 7B will also support avoiding contact with the rotating disk 180 surface. The central rail height 64 will also supporting avoiding contact with the disk 180 surface when the disk drive 110 parks the actuator assembly 158.

Preferably, the left deflection rail height 54 may be essentially equal to the right deflection rail height 74. Further, these heights 54 and 74 may be essentially equal to the depth D2 of the leading air bearing surface 4. Alternatively, these heights 54 and 74 may be greater than D2. Further alternatively, these heights 54 and 74 may be less than D2. These heights 54 and 74 may further be essentially equal to D2 minus D1.

As used herein, two quantities are essentially equal if they are refer to the same kind of quantity and are within manufacturing tolerances of each other. By way of example, height and depth may be the same kind of quantity. Manufacturing tolerances, unless otherwise stated, will be within ten per cent.

Alternatively, the left deflection rail height 54 may differ from the right deflection rail height 74. One of these heights 54 and 74 may be essentially equal to the depth D2 of the leading air bearing surface 4. One of these heights 54 and 74 may be greater than D2. One of these

heights 54 and 74 may be less than D2. One of these heights 54 and 74 may be essentially equal to D2 minus D1.

The height 64 of the central deflection rail 60 may be greater than at least one of the deflection rail heights 54 and 74. The central deflection rail height 64 may be essentially equal to at least one of the deflection rail heights 54 and 74. The central deflection rail height 64 may be essentially equal to both the deflection rail heights 54 and 74. The central deflection rail height 64 may be essentially equal to the depth D2 of the leading air bearing surface 4. The central deflection rail height 64 may be greater than the depth D2. The central deflection rail height 64 may be less than the depth D2. Further, the central deflection rail height 64 may be essentially equal to D2 minus D1.

In certain embodiments of the invention, the distance D3 of Figure 1B may typically be less than 15 nano-meters (nm) during normal access operations of the hard disk drive 110 of Figures 8 to 10. The distance D3 may further be less than 10 nm. The distance D3 may further be less than 5 nm. The distance D3 may further be less than 3 nm.

As shown in Figures 2A, F2B, 2B to 7B, the left deflection rail 50 and the right deflection rail 70 are preferably after the end of leading air bearing surface 4 and before the central island including region 14. The left deflection rail 50 and the right deflection rail 70 are preferably located around the principal axis 24.

Each of the deflection rails 50, 60, 70, 250 and 270 of Figures 2A to 7B, belong to the deflection rail collection as members. It may be preferred that at least one member of the deflection rail collection has a back face. It may further be preferred that each member of the deflection rail collection has a back face, as shown in the Figures 2A to 7A. By way of example, in these Figures, the left deflection rail 50 has a back face 50B. The central deflection rail 50 has a back face which is essentially parallel the leading edge 26. The right deflection rail 70 has a back face 70B in Figures 2A to 3B, and 5 to 7B. In Figures 4A and 4B, the back face of the right deflection rail 70 is bent, composed of a first back face 70B1 and a second back face 70B2, both of which are essentially straight.

It is preferred that the first gap G1 be sufficient that no additional sub-ambient pressure is generated when the slider 102 is in operation flying over the rotating disk 180 surface. It is

further preferred that the gaps G1, G2, and G3, of Figure 5 and 6A, are all sufficient that no additional sub-ambient pressure is generated.

In Figures 4A and 4B, the left deflection rail 50 has a curved shape and the right deflection rail 70 has a bent shape. While it is not shown, one skilled in the art will recognize that the invention includes embodiments where the left deflection rail 50 is also a bent shape. Also not shown, the invention includes embodiments where the right deflection rail 70 is a curved shape.

The invention includes embodiments using more than three deflection rails, similar in operation and construction to the deflection rails shown in the Figures 6A to 6D.

Figure 6A shows a refinement of Figure 5, further including a second left deflection rail 250 and a second right deflection rail 270.

Figures 6B to 6C shows refinements of Figures 2A and 2B, further including a second left deflection rail 250 and a second right deflection rail 270.

Figures 6D shows a refinement of Figures 2A and 2B, further including a second left deflection rail 250.

In Figures 6A to 6D, a fourth gap G4 separates the second left deflection rail 250 from the left deflection rail 50. In Figures 6A to 6C, a third gap G3 separates the second right deflection rail 270 from the right deflection rail 70.

Figure 7C shows a head gimbal assembly 160 including a slider 102 presenting the air bearing surface 100 and the read-write head 12. The slider 102 electrically couples to a flexure 106. The flexure 106 couples to a load beam 130. The head gimbal assembly may further, preferably include at least one micro-actuator 104. The coupling of the slider 102 to the flexure 106 may involve coupling through the one or more micro-actuators 104.

Figure 8 shows a hard disk drive 110 with actuator assembly 158 included in a voice coil motor assembly 118, containing actuator arms 150 to 156 which positions at least one head gimbal assembly 160 to 166.

Figure 9A shows a head disk drive 110, including the voice coil motor assembly 118 mounted through the actuator pivot 116 to the disk base plate 112. The voice coil motor

assembly 118, couples through the head gimbal assembly 160, to position the read-write head 12 over a rotating disk 180 surface.

Figure 9B shows a detail of Figure 9A. The actuator arm 150, coupling through the head gimbal assembly 160, positions the slider 102. The read-write head 12 accesses a track 190 on the rotating disk 180 surface.

Figure 10 shows a simplified, exploded view of the primary components of the hard disk drive 110 using the voice coil motor assemblies 118 of Figures G9 and 9A.

Consider the actuator arms 150 to 156 of Figures 8, 9A, and 9B. each of the actuator arms 150 to 156, contain at least one head gimbal assemblies 160 to 166. As shown in Figure 7C, each of the head gimbal assemblies 160 may use the sliders 102 of Figures 2A to 7B. The actuator assembly 158 includes the voice coil 114 rigidly coupled with at least one actuator arm 150 and collectively pivoting about the actuator pivot 116, as in Figure 9B.

The voice coil motor assembly 118 includes the actuator assembly 158, a top yolk plate 120 and a bottom yolk plate 122, as shown in Figure 8. The top yolk plate 120 rigidly couples over a top fixed magnet. The bottom yolk plate 122 rigidly couples to a bottom fixed magnet. The top and bottom fixed magnets are not visible in this Figure. The hard disk drive 110 is made in part by mounting the actuator assembly 158 through actuator pivot 116 to the disk base plate 112, as shown in Figure 9A. The read-write head 102 is positioned over a track 190 on a rotating disk 180 surface as in Figure 9B, by electrically stimulating the voice coil 114. The electrical stimulation of the voice coil 114 magnetically interacts with the fixed magnets coupled to the top and bottom yolk plate 120 and 122 to move the actuator arm 150 by lever action through the actuator pivot 116. The rotating disk 180 creates by friction a wind which is used by the air bearing surface to fly the slider 102. The read-write head 12 flies over the track 190 a small distance D3 off the rotating disk 180 surface, as in Figure 1B.

In certain embodiments of the invention D3 is less than 15 nano-meters (nm). In certain further embodiments, D3 may be less than 10 nm. D3 may further be less than 5 nm. D3 may further be less than 3 nm.

Those skilled in the art will appreciate that various adaptations and modifications of the described preferred embodiments may be configured without departing from the scope of the invention. Therefore, it is understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.